

**BRODIAEA MATSONII** (ASPARAGACEAE: BRODIAEOIDEAE) A NEW SPECIES  
FROM SHASTA COUNTY, CALIFORNIA

ROBERT E. PRESTON

ICF International, 630 K Street, Suite 400, Sacramento, CA 95814  
rpreston@icfi.com

ABSTRACT

A newly recognized endemic species, *Brodiaea matsonii*, is described. This highly localized species is restricted to a single extended population along Sulphur Creek, in Redding, Shasta County, California. *Brodiaea matsonii* is a diploid species ( $n = 6$ ) closely related to the more widespread *B. minor*, a polyploid species ( $n = 12, 24$ ), from which it differs by the slightly smaller pink flowers and by its habitat parameters. *Brodiaea matsonii* grows from cracks and crevices in bedrock along an intermittent stream within foothill woodland.

Key Words: Asparagaceae, *Brodiaea*, California, endemism, new species.

In 1993, Gary Matson discovered an unusual pink-flowered brodiaea growing along Sulphur Creek, north of Redding, California. Initial attempts to identify the plants suggested a relationship with *Brodiaea pallida* Hoover, a species known from only three other populations in Calaveras and Tuolumne counties, a disjunction of ca. 335 km. Mr. Matson collected corms from the population and gave them to Dean Taylor, an expert on California's rare plants. Dr. Taylor, in turn, presented me with a pot of the corms in 2007 at a symposium sponsored by the Northern California Botanists, where I gave a presentation on brodiaeas.

In late May, when the plants bloomed, I recognized that they were not *B. pallida* but morphologically were more similar to *B. minor* (Benth.) S. Watson. Further investigations of the Sulphur Creek population, including field surveys, morphological measurements, and chromosome counts show that the population is sufficiently distinct to warrant recognition at species rank.

TAXONOMIC TREATMENT

*Brodiaea matsonii* R. E. Preston, sp. nov. (Fig. 1).—Type: USA, California, Shasta Co., Redding, on S side of Keswick Dam Rd, 0.4 mi NE of its junction with Quartz Hill Rd, along W Branch of Sulphur Creek; 40°37'13"N, 122°25'25"W, elev. 700 ft, 24 Jun 2009, R. E. Preston 2689 (holotype: DAV; isotypes: JEPS, MO, NY, RSA, US).

Paratypes: USA, CALIFORNIA. **Shasta Co.:** Redding, Upper Sulphur Creek, *D. W. Taylor s.n.* (JEPS); Redding, along Sulphur Creek, S of Keswick Dam Rd crossing, 04 Jun 2007, R. E. Preston 2548 (DAV); west fork of Sulphur Creek, 04 Jun 2007, R. E. Preston 2547 (JEPS).

Differt a *B. minor* perianthio roseo, costis abaxialibus viridibus, et lobis apicem versus et costis adaxialibus saepe erubescensibus.

Corm with coarse fibrous coat, 1–10 cm below ground level; leaves 2–5, subrescent-shaped in cross-section, less than 15 cm long; peduncle slender, 10–25 cm tall, pedicels less than 36.5 mm long; perianth 17.4–26.7 mm long, tube urceolate, 6.8–9.4 mm long, lobes ascending, 10.6–17.5 mm long, outer oblong, acute, 3.0–4.2 mm wide, inner oblanceolate, rounded, 3.6–5.2 mm wide, white to pink, tips and abaxial mid-ribs rose, adaxial mid-ribs green; staminodes 6.2–8.5 mm long, erect and approximate to stamens, lanceolate, white, margin entire, involuted; stamens 4.8–6.4 mm long, filament 2.0–2.8 mm long, tapered to wider base, narrowly winged laterally, anther 4.0–5.1 mm long, linear, tips of anther lobes erect with V-shaped notch between; ovary obovate, 3.8–5.6 mm long, style 6.5–9.2 mm long, slightly wider near apex, ovules 5–8 per locule; fruit a loculicidal capsule, ellipsoidal, 5–6 mm long, 3 mm wide, valve apex acute; seeds black, ovoid to rhomboid, finely striate, 1–1.5 mm long.

Chromosome number  $n = 6$  (Fig. 2). The chromosome count was performed on root tip cells from corms collected with R. E. Preston 2548 (DAV) (A. Diebold, University of Missouri-Columbia, personal communication).

The species is named for its discoverer, Gary Matson (1949–1999), horticulturalist and founder of the Redding Arboretum (Howe et al. 2000). I suggest “Sulphur Creek brodiaea” as the common name.

DISTRIBUTION, CONSERVATION, AND ECOLOGY

Sulphur Creek brodiaea is restricted to a single occurrence in Shasta Co., California. The species is among the rarest taxa in California, consisting



FIG. 1. *Brodiaea matsonii*. a) Lateral view of inflorescence; b) lateral view of flower; c) oblique view of flower; d) top view of flower.

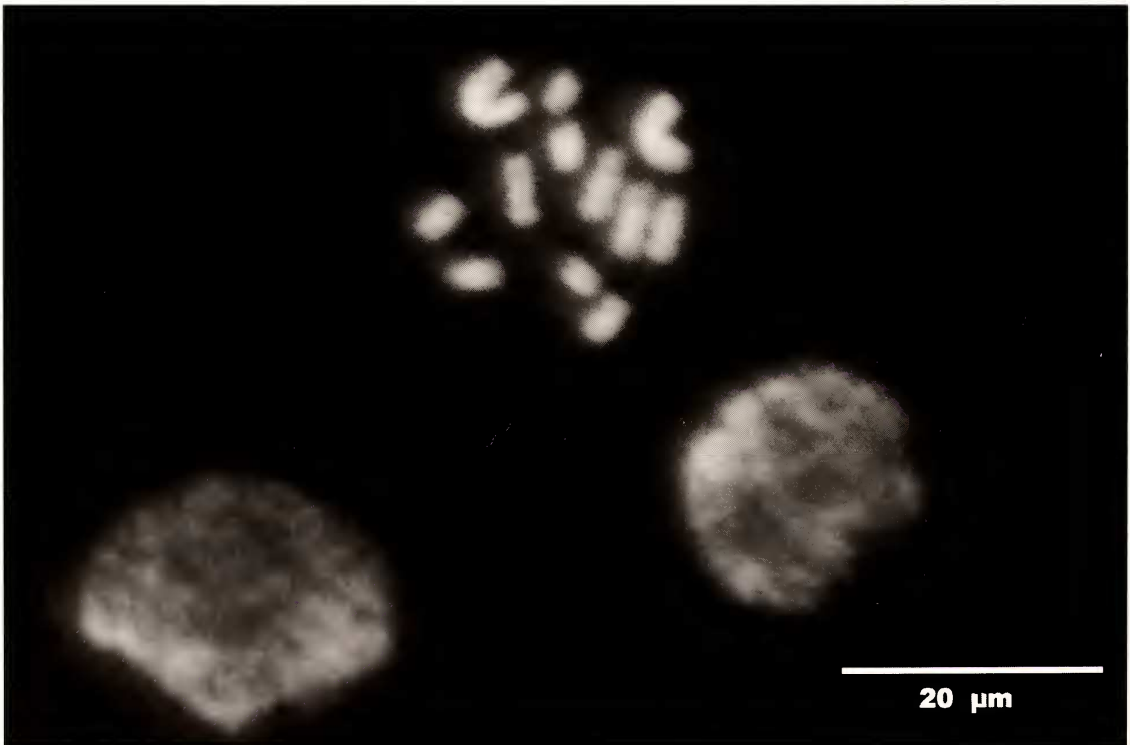


FIG. 2. Chromosomes of *Brodiaea matsonii* from root tip cells (based on R. E. Preston 2548 [DAV]),  $2n = 12$  (photograph provided by A. Diebold, University of Missouri-Columbia).

TABLE 1. COMPARISON OF FLORAL CHARACTERS FOR *BRODIAEA MINOR*, *B. NANA*, AND *B. MATSONII*. Measurements were made on fresh material, from one flower per plant, from the type locality of *B. matsonii*, from 20 populations of *B. minor*, and from 16 populations of *B. nana*. Measurements in mm.

Character	<i>Brodiaea nana</i> (n = 170)		<i>Brodiaea minor</i> (n = 204)		<i>Brodiaea matsonii</i> (n = 24)	
	mean	range	mean	range	mean	range
Perianth tube	7.3	5.0–9.0	8.6	6.5–11.5	8.0	6.8–9.4
Perianth lobes	14.3	10.0–21.0	15.0	9.8–20.5	13.5	10.6–17.5
Width, inner lobes	5.2	4.0–8.0	4.7	3.0–7.0	4.5	3.6–5.2
Width, outer lobes	3.8	3.0–5.0	3.7	2.8–5.0	3.6	2.9–4.2
Staminode	7.2	6.0–9.0	9.1	6.2–12.5	7.6	6.2–8.5
Filament	1.4	1.0–2.0	2.4	1–4.2	2.3	2.0–2.8
Anther	4.0	3.0–5.0	5.2	3.5–7.0	4.5	4.0–5.1
Stamen	4.4	3.5–5.2	6.4	4.5–9.0	5.8	5.0–6.6
Ovary	3.5	2.2–5.0	4.9	3.2–7.0	4.5	3.8–5.8
Style	5.3	4.0–7.5	8.8	6.0–12.0	7.9	6.5–9.2
Ovule number	22.5	12–33	17.3	12–24	20.4	15–24

of only a few hundred individuals scattered along a 1.6 km reach of stream channel. The population grows from cracks and crevices in bedrock along the banks and on small rocky islands within the channel of Sulphur Creek, an intermittent stream occurring within foothill woodland. The canopy is characterized by *Quercus douglasii* Hook. & Arn., *Q. wislizeni* A. DC., and *Pinus sabiniana* Douglas, with a shrub understory of *Ceanothus cuneatus* (Hook.) Nutt., *Arctostaphylos viscida* C. Parry, and *Toxicodendron diversilobum* (Torr. & A. Gray) Greene. Associated species include *Sidalcea hirsuta* A. Gray, *Centaureum venustum* (A. Gray) Robinson, and *Holozonia filipes* (Hook. & Arn.) Greene. The Sulphur Creek watershed lies in the region where the Klamath Range, with its predominantly metamorphic geology, intergrades with the predominantly volcanic Cascade Range Foothills. Soils in the area, mapped as Auburn clay loam (Klaseen and Ellison 1974), are formed in material weathered from amphibolite schist, which outcrops extensively along this section of the stream. The elevation ranges from 195 to 215 m above mean sea level.

#### PHENOLOGY

Like all brodiaeas (Niehaus 1971), Sulphur Creek brodiaea forms corms that are dormant in the soil during the summer drought. New leaves emerge soon after the start of the rainy season, generally in October or November. Similar to the process described for *Triteleia laxa* Benth. (Han et al. 1994; Schlising and Chamberlain 2007), the plants spend the next six months or so producing a new main corm and one to many small offsets. Blooming occurs in late May and June, generally two to three weeks later than populations of *B. minor* in the Redding area. Seed set follows soon after, and all above-ground parts wither and dry during the summer dormant period.

#### TAXONOMIC RELATIONSHIPS

The genus *Brodiaea* Smith remains a valuable resource for systematic and ecological investigation, despite having been monographed twice (Hoover 1939; Niehaus 1971). Recent treatments of *Brodiaea* recognized 14 species and eight subspecies (four species each with two subspecies), most of which are entirely restricted to the California Floristic Province (Niehaus 1971; Keator 1993; Pires 2002). Clarification of some species circumscriptions (Preston 2006a, b) and new species descriptions (Preston 2006b; Chester et al. 2007) have altered these totals, and the forthcoming second edition of The Jepson Manual will recognize 18 species, two of which have two subspecies apiece (Pires and Preston in press). The description of *Brodiaea matsonii* brings the total number of currently recognized *Brodiaea* taxa to 21, and additional morphometric and phylogenetic studies currently underway are likely to raise that total by several more species.

*Brodiaea matsonii* appears to be most closely related to *B. nana* Hoover, *B. minor*, and *B. pallida*, based on the morphological similarities between them. The flowers of *B. matsonii* are slightly smaller, on average, than *B. minor*, and they are somewhat intermediate in size between *B. minor* and *B. nana* (Table 1). However, the shape of the stamens and staminodes are closer in all respects to those of *B. minor*, rather than *B. nana* or *B. pallida* (see Figure 1 in Preston [2006a] for comparison of *B. minor* and *B. nana*, and Hoover [1938] for a discussion of *B. pallida*). The main morphological difference between *B. matsonii* and *B. minor* is the pink (vs. blue-violet) flowers. *Brodiaea* species typically have violet flowers, and plants with pink flowers, while not unknown, are unusual. *Brodiaea rosea* (Greene) Baker was originally recognized and described on the basis of its pink flowers. *Brodiaea californica* Lindl. has several pink-flowered populations in



the Battle Creek/Paynes Creek watershed in Tehama and Shasta counties (Rowntree 1936) and at least two populations of *B. sierrae* R. E. Preston have individuals with pink flowers (personal observation; G. Hartwell, Paradise, CA, personal communication). Although pink-flowered cultivars of the latter two species have been named (Burbanck 1941), intraspecific taxa have not been proposed for either species on the basis of flower color.

All four of these species are characterized by small flowers (generally <2.5 cm long) with a perianth tube narrowed above the ovary. The urceolate perianth tube appears to be a synapomorphy, as the perianth tube is campanulate or funnel-shaped in all other *Brodiaea* species. Hoover (1939) proposed a series of intrageneric groups of species he felt were related, based primarily on morphological grounds, and he placed *B. nana*, *B. minor*, and *B. pallida* along with *B. stellaris* S. Watson in an informal Section "Stellares". Niehaus (1971) later added *B. insignis* (Jeps.) Niehaus to this group. However, *B. stellaris* and *B. insignis* lack an urceolate perianth tube and possess other morphological differences that indicate that they are probably not closely related to the other species included in section "Stellares". Reliance on morphological data alone has proved of limited usefulness in resolving relationships between and among *Brodiaea* species, and further work is needed.

Because *B. matsonii* consists of a single population and is morphologically similar to *B. minor*, what is the basis for recognizing *B. matsonii* at species rank and not just as a variety or subspecies of *B. minor*? A review of species circumscription within *Brodiaea* provides the context needed to justify this decision.

Taxonomic circumscriptions within *Brodiaea* traditionally have been grounded on the morphological species concept. Species have generally been distinguished on the basis of discrete differences in the shape of the floral parts, whereas taxa delineated on the basis of size differences or the relative position of floral parts have been treated as varieties or subspecies. Unfortunately, all *Brodiaea* species are superficially similar, and determining diagnostic characters among species based primarily on floral characters can be difficult, especially when using pressed specimens (Smith 1811; Greene 1886; Hoover 1939). Historically, *Brodiaea* has been much more broadly circumscribed, and the common name "brodiaea" is still applied to species now segregated among several genera, including *Dichelostemma* Kunth and *Triteleia* Dougl. ex Lindl. Although *Brodiaea* appears closely related to *Dichelostemma*, *Triteleia* appears to be only distantly related (Pires and Sytma 2002). In addition, the presence of umbels, corms, and other morphological similar-

ities between *Brodiaea* and other lilioid geophytes has made higher order classifications difficult, and *Brodiaea* has been placed variously in Liliaceae, Amaryllidaceae, Alliaceae, and Themidaceae (Hoover 1939; Keator 1989; Niehaus 1971, 1980; Fay and Chase 1996). The most recent phylogenetic classification based on molecular data, places *Brodiaea* and relatives with the Asparagaceae in the subfamily Brodiaeioideae (Chase et al. 2009).

Hoover (1939) epitomized the traditional, morphological approach to species circumscriptions in *Brodiaea*. Hoover was familiar with the concepts of ecotypes and ecological plasticity, invoking these ideas to explain some of the intraspecific variation that he observed in *Brodiaea*, although he did not apply ecological information to inform his taxonomic treatment. He was also limited by the lack of cytological data for *Brodiaea* species. Hoover recognized ten *Brodiaea* species, six of which exhibited minimal intraspecific variation. He reduced four other previously-described species to varieties, citing morphological intermediacy as the basis for his changes in rank. He reduced *B. nana* to a variety of *B. minor*, stating that the two taxa intergraded completely. He treated *B. leptandra* Greene as a variety of *B. californica*, stating that he could find few morphological differences between the two taxa. He recombined *B. terrestris* Kellogg as *B. coronaria* (Salisb.) Engl. var. *macropoda* (Torr.) Hoover, stating that the primary difference between *B. terrestris* and *B. coronaria* was the length of the scapes and pedicels, and that the floral morphology was nearly identical. He treated *Brodiaea rosea*, a rare serpentine endemic known from only a few locations in Lake, Glenn, and Colusa counties as a variety of *B. coronaria*, downplaying the morphological differences between them. Hoover also extended the morphological species concept to brodiaeas in the broad sense. He reduced *Triteleia modesta* H. M. Hall Hoover and *T. leachiae* M. Peck Hoover to varieties (of *T. crocea* Greene and *T. hendersonii* Greene, respectively), noting that the varieties differed morphologically in only minor aspects from the typical forms, except for flower color (Hoover 1941). Hoover later took an approach more in line with the biological species concept (Mayr 1963; Grant 1981), re-elevating *B. leptandra* to species rank on the basis of reproductive isolation, despite its morphological similarity to *B. californica* (Hoover 1955). He also proposed raising morphologically similar varieties of *T. ixioides* Greene to species rank on the basis of genetic isolation through ecological and geographic separation (Hoover 1955).

Niehaus (1971) employed a multifaceted approach to try to get beyond the morphologically-based species concept that limited Hoover's understanding of species' boundaries and the

evolutionary relationships among the species. He attempted to incorporate multiple data sources, including morphology, anatomy, cytology, flavonoid chemistry, hybridization studies, geography, and ecology, to circumscribe *Brodiaea* species. Niehaus' treatment was in accord with the biosystematic species concept (Grant 1981), in which species are defined by reproductive isolation as a consequence of genetic or ecological factors, or both. Niehaus agreed with Hoover's acceptance of *B. leptandra* at species rank, citing differences in morphology, chromosome number, range, habitat, and flowering phenology that distinguished it from *B. californica*. He similarly restored *B. coronaria* var. *macropoda* to species rank (*B. terrestris*) based on morphology, distribution, and chromosome number. He also recognized *B. nana* at species rank, distinguished from *B. minor* on the basis of chromosome number, distribution, and habitat (albeit as *B. minor* and *B. purdyi* Eastw., respectively, as Niehaus had difficulty circumscribing the two species for other reasons [Preston 2006a]).

Niehaus was not entirely consistent in his approach and maintained several subspecies despite noting differences in morphology, chromosome number, and distribution from the typical subspecies. He maintained *B. coronaria* subsp. *rosea* (Greene) Niehaus, although he noted that it was a serpentine endemic with a highly restricted range. He also recognized octoploid ( $n = 24$ ) populations of *B. terrestris* as subsp. *kernensis* (Hoover) Niehaus, despite substantial morphological differences and non-overlapping ranges with hexaploid ( $n = 18$ ) subsp. *terrestris*. He described polyploid ( $n = 20$ ) populations of *B. elegans* Hoover as subsp. *hooveri* Niehaus, even though differences in staminode morphology and distribution distinguish them from  $n = 8$  and  $n = 16$  populations.

Following the traditional, morphologically-based species concept, *B. matsonii* might not warrant recognition at species rank. However, based on the biosystematic species concept, *B. matsonii* does appear to warrant recognition at species rank. It appears to be reproductively isolated from *B. minor* by a combination of factors, including chromosome number, habitat preference, flowering phenology, and allopatry.

Although *B. matsonii* is morphologically similar to *B. minor*, they have different chromosome numbers. The base chromosome number in *Brodiaea* is  $n = 6$ ; the majority of taxa are polyploid with  $n = 12, 18,$  and  $24$ , although *B. elegans* is diploid, having  $n = 8, 16,$  and  $20$  cytotypes (Johansen 1932; Burbank 1941; Niehaus 1971). *Brodiaea matsonii* is a diploid, along with seven other species including *B. nana* and *B. pallida*. In contrast, *B. minor* appears to consist of a complex of polyploid populations, with populations at lower elevations in the Sierra Nevada

and Cascade Range foothills reported to be octoploid ( $n = 24$ ) and populations at higher elevations in the Sierra Nevada reported to be tetraploid ( $n = 12$ ) (Niehaus 1971). *B. matsonii* appears to be genetically isolated from *B. minor*, therefore, as hybrids between *Brodiaea matsonii* and *B. minor* would not be expected to be fertile. Niehaus (1971) found that interspecific hybrids had reduced seed set and reduced pollen fertility, and he stated that few interspecific hybrids were known where *Brodiaea* species occurred sympatrically.

Traditionally, cytotypes that lack clear differences in morphology, ecology, or distribution have not been recognized as separate taxa, and this approach has also been followed for brodiaeas, both in the narrow and broader sense. Niehaus (1971) acknowledged that several *Brodiaea* species consisted of cytotypes with two or more ploidy levels but declined to recognize taxa based on chromosome number unless there was a clear morphological boundary between them. Keator (1968) found that *Dichelostemma capitatum* (Benth.) Alph. Wood consisted of multiple cytotypes but was unable to identify morphological or ecological differences between them. Similarly, Barkworth (1977) studied polyploidy populations of *Triteleia douglasii* Watson and found no consistent morphological characteristics that could be used to recognize intraspecific taxa. In the case of *B. matsonii*, however, flower color and ecology clearly distinguish it from *B. minor*.

*Brodiaea matsonii* has very different habitat parameters than *B. minor*. The association of *B. matsonii* with ephemeral stream habitat is very rare within *Brodiaea*. *Brodiaea pallida* similarly occurs along intermittent streams; the population along Sawmill Creek in Calaveras Co. also occurs in blue oak-foothill pine woodland on outcrops of amphibolite schist within the stream channel and along the banks (personal observation). In southern California, *B. filifolia* S. Watson, which generally grows in grasslands and on vernal pool margins, rarely grows from cracks and crevices in bedrock along stream banks (T. Chester, Fallbrook, CA, personal communication). In contrast, *B. minor* occurs across a wide range of habitats, including grassland, vernal pool, seep, meadow, and chaparral, often on substrates of volcanic origin, but also on serpentine and gabbro. However, none of the known populations of *B. minor* occur along streams; if any do so, they must be extremely uncommon. Populations of *B. minor* in Redding, some of which are less than a mile from the occurrence of *B. matsonii*, occur in and adjacent to vernal pools on old alluvial terraces, generally where a hardpan is present. *Brodiaea nana* is also not known to occur along streams, but like *B. matsonii* and *B. pallida*, *B. nana* is associated with a much narrower range of habitats. It is



found primarily in vernal pools, although it also occurs in grassland on thin soil overlying bedrock, where soils become waterlogged following precipitation.

Vernal pools and intermittent streams are both seasonal wetland habitats, having saturated soils during the winter rainy season but drying down during the summer drought. Vernal pools occupied by *B. nana* and *B. minor* typically dry down by mid-April, whereas the intermittent streams occupied by *B. matsonii* and *B. pallida* remain wet until mid-May or later. This extended hydroperiod is reflected in these species flowering phenology. *Brodiaea nana* and *B. minor* populations that occur in vernal pool terrain bloom in April and early May, whereas *B. matsonii* and *B. pallida* populations bloom in late May and early June. Although flowering date in *Brodiaea* species is ecologically plastic with respect to annual variation in spring temperatures and rainfall (Niehaus 1971), the later blooming dates of *B. nana* and *B. pallida* appears to have a genetic basis as well, because both *B. matsonii* and *B. pallida* bloom later than *B. nana* and *B. minor* under common garden conditions (personal observation).

Recent studies based on molecular data have proved useful for understanding relationships within the Brodiaeoideae and may point a way towards resolving species relationships within *Brodiaea* (Pires and Sytsma 2002). A phylogenetic analysis of *Brodiaea* and *Dichelostemma* based on DNA sequences is currently underway that may help to interpret morphological characters and to identify the origin of polyploid lineages, especially those involving cryptic cytotypes. Preliminary results based on ITS sequences indicate that *B. matsonii* is grouped with a clade that is basal to the clades containing *B. minor* and *B. nana* (A. Diebold, University of Missouri-Columbia, personal communication). If that relationship is confirmed by the full analysis, then it would add further support to the recognition of *B. matsonii* at species rank.

Key to the *Brodiaea* Species with the Perianth Narrowed Above the Ovary

- 1a. Stamines erect to spreading, margins strongly inrolled; stamens narrowly notched at apex, lacking prominent papillae abaxially; filaments winged laterally, T-shaped in cross-section.
  - 2a. Perianth violet, outer mid-ribs red-violet . . . . . *B. minor*
  - 2b. Perianth pink, outer midribs green, lobe tips and upper inner midribs often rose-pink . . . . . *B. matsonii*
- 1b. Stamines erect, margins not to slightly inrolled; stamens broadly V-shaped at apex, with prominent abaxial papillae; filaments winged abaxially, V- or Y-shaped in cross section.
  - 3a. Perianth lobes paler towards the base; perianth tube slightly narrowed above the

- ovary; staminodes as broad as or broader than the outer perianth lobes. . . . . *B. pallida*
- 3b. Perianth color uniform; perianth tube strongly narrowed above the ovary; staminodes narrower than outer perianth lobes . . . . . *B. nana*

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